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THE EFFECT OF THE BINDER ON THE PROPERTIES OF ELECTROCORUNDUM ABRASIVE TOOLS

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The effect of the chemical composition of the binder on the properties of electrocorundum abrasive tools is studied. Compositions of ceramic binders before and after firing of tools are analyzed.

The main parameters of an abrasive tool based on a ceramic binder determining the service properties of the tool are the grain size and hardness of the abrasive material and the working speed. At the same time the service properties of abrasive tools are determined by the quantity of abrasive cutting grains and their shape, the layout and type of fixation of abrasive grains in the working layer of the tool, i.e., the macrostructure of the abrasive composition, and the type of bond of the abrasive to the binder.

In developing abrasive tools with the required grain size of the abrasive material, the degree of hardness and the working speed of the grinding wheel are regulated by the content and composition of the binding components, which fix abrasive grains in the wheel, disintegrates when the grains become blunt or worn, and lets free new cutting grains. The studies in [1, 2] give the results of studying the correlation between the degree of hardness and the content of abrasive material, the amount of binder, and the porosity of abrasive composition. Furthermore, the authors note that the hardness of composites with an equal content of abrasive material depends on the composition of the binder and the tool firing temperature. However, the regularities obtained are not universal, and manufacturing companies have to compile experimental tables of correlations between abrasive materials and binders for various degrees of hardness taking into account the technological conditions and the materials used.

A binder in an abrasive tool takes up about 10% of the total volume and is distributed over abrasive grains forming bridges of size 5 – 150 μm. As a rule, binders are compared based on the bending and breaking strength of abrasive composites prepared with binders of different compositions. However, this comparison is rather arbitrary, since the strength of a composite depends not only on the strength of the bond between abrasive grains and binder but also on the composite density determined by contents of abrasive material and binder and by the size of pores. Research of the strength of abrasive electrocorundum-based composites with various grain sizes using different binders revealed that the effect of the strength of adhesion of abrasive material to a binder on the macrostrength of the abrasive composite is insignificant. The modification of the inner structure of the abrasive composite and, accordingly, the increase or decrease in its strength are related to the modification of the composite density due to the increased content of abrasive in the tool or variations in the pore size as a consequence of changes in the granular composition of the abrasive material. The hardness of the composite varies in a similar way.

The degree of hardness is determined by sandblasting the surface of the abrasive instrument (based on the depth of the surface destruction), or by the method of indenting a ball. Evidently, the depth of destruction of the tool surface in measuring hardness depends on the size of the strongest element (abrasive grain), on the strength and thickness of the binder between the grains, and on the size and quantity of pores.

Special graduation scales have been developed for evaluating the hardness of tools made of electrocorundum of various grain sizes. A method has been developed for nonintrusive acoustic control of hardness, which determines the hardness of a tool graded in letters based on correlation dependences. This method is based on a correlation of elastic parameters, such as natural vibration frequency, the speed of acoustic wave propagation (S1), and the elasticity modulus (Young's modulus) with the composition and properties of the wheel material. The speed of propagation of acoustic waves is measured with a Zvuk instrument [3], the degree of hardness is found from tables developed, and the Young modulus is calculated. Provided that the condition of a stable volumetric structure in the abrasive composite compared is satisfied, the strength of cohesion of binder to abrasive grains can be estimated based on the Young's modulus.

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TABLE 1

Binder brand	Mass content, %					
	SiO_2	Al_2O_3	B_2O_3	R_2O*	R_2O_3 and RO_2**	RO***
			First group			
1-5	62.5 – 64.5	17.0 – 20.5	5.3 – 6.7	5.8 – 8.0	1.2 – 1.7	3.7 – 3.9
1-20	63.5 – 64.5	19.2 – 20.5	3.5 – 3.8	7.0 – 7.5	2.0 – 2.5	2.5 – 2.9
			Second group			
2-1	60.1 – 61.3	14.1 – 15.5	4.3 – 4.9	10.5 – 11.5	2.3 – 2.6	4.5 – 4.8
2-2	59.5 – 60.6	18.1 – 18.5	3.9 – 4.3	9.1 – 9.7	3.2 – 3.6	4.2 – 4.5
2-3	62.1 – 62.8	18.9 – 19.5	2.1 – 2.8	9.5 – 9.7	2.2 – 2.6	3.0 – 3.2
2-4	60.1 – 60.8	14.0 – 14.8	4.5 – 4.9	10.5 – 11.5	3.5 – 3.9	5.5 – 6.1
2-5	63.1 – 63.6	17.9 – 18.5	4.0 – 4.2	8.5 – 8.9	2.3 – 2.5	2.9 – 3.6

* For the first group of binders $R_2O = K_2O, Na_2O$. For the second group of binders $R_2O = K_2O, Na_2O, Li_2O$.

** For the first group of binders $R_2O_3 + RO_2 = Fe_2O_3$. For the second group of binders $R_2O_3 + RO_2 = Fe_2O_3, Mn_2O_3, Cr_2O_3, TiO_2$.

*** For the first group of binders RO = CaO, MgO. For the second group of binders RO = CaO, MgO, ZnO.

TABLE 2

Grinding wheel size	Grade and grain size of abrasive	Binder brand	Acoustic index	Hardness degree
150 × 10 × 32	25A40	2-1	51	S1
150 × 10 × 32	25A40	2-2	49 – 51	SM2 – S1
150 × 10 × 32	25A40	2-3	51	S1
150 × 10 × 32	25A40	1-20	49	SM2
200 × 25 × 32	25A16	2-4	35	M2
200 × 25 × 32	25A16	1-20	33	M1
200 × 5 × 32	25A40	2-5	47	SM1
200 × 5 × 32	25A40	1-20	45	SM1
70 × 7.7 × 17.5	25A12	2-5	53 – 55	S2 – ST1
70 × 7.7 × 17.5	25A12	1-5	53	S2

Despite a substantial amount of experimental studies in the field of development of new ceramic binder compositions and upgrade of the technology of production of abrasive tools using ceramic binders, it is not always clear in what way modification of the binder composition affects the service parameters of the tool (degree of hardness, actual porosity, and mechanical strength). To determine the advisability of transition to new materials in the production of binders or replacement of binders for economic or technological reasons, it is necessary to investigate the effect of the composition of ceramic binders on the properties of abrasive composites.

The present paper shows the results of studying the effect of the composition and content of a binder on the degree of hardness of abrasive tools and compares the properties of abrasive wheels using ceramic binders of two groups. The first group includes binders that are represented in a tool by heterogeneous glass bridges with inclusions of new crystalline formations or residual crystals, and the second group contains binders represented in the tool by homogeneous glass bridges.

Table 1 lists the compositions and properties of ceramic binders investigated in this study converted to oxides. The main distinction of the composition of the second group of binders is the high content of modifier oxides introduced into the binder via frit [3]. The content of SiO_2 in the binders of the first and the second group is very close, whereas the content of Al_2O_3 is lower and the content of alkaline oxides and $(R_2O_3 + RO_2)$ oxides is higher in binders of the second group.

Several grinding wheels with different parameters were prepared with an equal mass content of binder in the compositions. The properties of the wheels investigated are shown in Table 2.

Table 3 shows estimated binder compositions in tools made of white electrocorundum after firing, i.e., taking into account the modifications of initial compositions due to dissolution of electrocorundum (Al_2O_3) grains in binders under firing and its reaction with sodium silicate used as a temporary binder.

TABLE 3

Binder group	Mass content, %					
	SiO_2	Al_2O_3	B_2O_3	R_2O	R_2O_3	RO
First	57.0 – 58.0	23.0 – 28.0	3.0 – 6.0	6.5 – 7.0	1.1 – 2.0	2.5 – 3.5
Second	53.0 – 55.0	24.0 – 27.0	3.0 – 4.0	8.5 – 10.5	3.0 – 3.3	3.7 – 5.5

The content of dissolved Al_2O_3 was found by the chemical method. Modifications of the contents of Na_2O, SiO_2, and Al_2O_3 in the final composition of the binder were calculated based on the quantity of temporary binder introduced into the molding mixtures and the content of dissolved Al_2O_3.

Binders of the first group in firing dissolve 1.5 – 2.5 wt.% aluminum oxide of electrocorundum depending on the grain size of abrasive, and binders of the second group dissolve 2.5 – 3.5 wt.%. At the same time modifications of the size of electrocorundum grains caused by their reaction with melted binder and sodium silicate is measured by a micrometer. A calculation of the binder composition in abrasive tools supports the conclusion that compositions of the first group cannot be obtained in the form of glass at the tool firing temperature, and compositions of the second group, despite an increased content of aluminum oxide, can form glass.

Microscopic studies performed earlier [4, 5] established that the contact zone between the binder and the corundum grains in samples containing binders of the first group is a heterogeneous porous vitreous layer with crystalline inclusions (residual quartz, mullite), and the contact zone in samples of the second group constitutes a glass layer 0.01 – 0.03 μm thick. It is assumed that Al_2O_3 in firing is nearly uniformly distributed in the glass interlayers formed in the course of firing. The strength of abrasive tools with binders of the second groups is higher than the strength of the tools based on binders of the first group. The acoustic index of wheels based on the first group of binders exceeds to some extent the acoustic index of wheels on binders of the second group, which agrees with the correlation between the acoustic index and the Young's modulus characterizing the strength of materials.

As a consequence of comparison of properties of abrasive wheels on different binders, it was found that a binder has virtually no effect on the standard specifications of abrasive tools specified on products according to regulatory documents, but the binder composition determines the macrostructure of abrasive composite and the strength of the tool.

The data discussed in this paper make it possible to predict the service properties of abrasive electrocorundum tools depending on the binder composition.

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